INVESTIGATION OF AIR QUALITY ASSOCIATED WITH SMOKE FROM AGRICULTURAL STUBBLE BURNING

AUGUST - OCTOBER, 1989

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ABSTRACT

In response to public concern regarding the effects of smoke produced from agricultural stubble burning, and to complement data collected in 1987, a study was undertaken in the fall of 1989 to monitor particulate levels, polynuclear aromatic hydrocarbons (PAH), and volatile organic compounds (VOC), during smoke events in the vicinity of Winnipeg.

Elevated levels of both total and inhalable particulate were observed during known smoke incidents in the vicinity of Winnipeg. None of the total suspended particulate levels were found to exceed the Maximum Acceptable Limit of 120 ug/m^3, as set out in the Manitoba Air Quality Objectives.

Elevated levels of PAH and VOC were observed, in comparison to background, during known incidents of agricultural burning. Compound profiles were similar to those observed during a preliminary study conducted in 1987.

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BACKGROUND

Public concern has been raised regarding the effects of smoke produced from the burning of agricultural residues such as stubble and excess straw. These events usually occur in the fall, after harvesting has been completed. Incidents routinely produce large amounts of smoke, obscuring visibility on roads, and occasionally causing hazardous driving conditions. Potential health effects have also been reported, especially among individuals suffering from respiratory disorders.

In 1987, public hearings were held by the Manitoba Clean Environment Commission to address this issue. Section 5.4.1.2 of the commission report recommended that "samples from the burning of peat and stubble be analyzed by the Department of Environment for the compounds which may be responsible for deleterious effects on human health and the analytical results be given to the Manitoba Department of Health". (1)

Little literature has been published regarding the combustion products produced as a result of agricultural burning. An initial study was conducted during the fall of 1987 (2) to provide preliminary data on emissions from this source. The information contained in this report is intended to supply further information from surveys conducted during smoke incidents in 1989.

To characterize emissions from this source, three parameters were examined in this study:

1) Particulate levels - Total and Inhalable
2) Polynuclear Aromatic Hydrocarbons
3) Volatile Organic Compounds

Total suspended particulate (TSP), is defined as particles in the solid or liquid phase which exist in a size and configuration that allows them to remain suspended in ambient air. Major contributors to TSP levels within urban centres are emissions from industrial plants, secondary particulate formation (smog), and entrainment of dust from agricultural areas during high wind conditions. Forest fires and other major combustion sources have also been found to contribute significantly to elevated TSP levels.

Inhalable particulate is a sub-class of TSP, and may be defined as solid or liquid particles which not only may remain suspended in air, but also are of a size which allows them to penetrate into the tracheobronchial and alveolar regions of the lung in a living organism, causing distress and contributing to respiratory disorders. Studies have established that particles with an aerodynamic diameter of less than 10 micrometres are susceptible to this process (3).

Polynuclear aromatic hydrocarbons (PAH) are a class of compounds in which single aromatic rings have been fused into chains of various configurations. PAH are routinely produced as a result of incomplete or low temperature combustion, and have been found to constitute a significant component of both particulate and gaseous smoke emissions. Particulate PAH are primarily in the respirable range (<10 micrometres).

Evidence presented by various researchers indicates that certain polynuclear aromatic hydrocarbons are toxic, and are identified as priority pollutants (4, 5, 6, 7, 8). Some of these compounds have been implicated as carcinogens, co-carcinogens, or respiratory irritants.

Volatile organic compounds (VOC) is a term used to describe selected organic compounds in the alkane, aromatic, alkyl halide and halogenated aromatic categories. Monitoring has been undertaken by Environment Canada (9, 10) to quantify ambient levels of these compounds, and to identify industrial point sources of emission. A number of the VOC examined in this study have known or suspected carcinogenic properties.

The following objectives were defined for this study:

1) To determine levels of ambient particulate, both total and inhalable, during known smoke events in the vicinity of Winnipeg.

2) To examine PAH emissions during events of this nature, and to determine if elevated concentrations of these compounds are observed.

3) To measure ambient VOC levels in the area during smoke episodes,and to determine ambient levels of these compounds.

MANITOBA AIR QUALITY OBJECTIVES AND GUIDELINES

The Manitoba Government has adopted criteria for various air pollutants. These criteria are known as the Manitoba Air Quality Objectives and Guidelines (Environmental Management Division, 1985). The maximum levels for total suspended particulate are presented in Table 1. The establishment of objectives and guidelines are based upon three assessment levels:

1. Maximum Tolerable Level (M.T.L.)
   This level denotes a time-based concentration of air contaminant beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

2. Maximum Acceptable Level (M.A.L.)
   This level is deemed essential to provide adequate protection for soils, water, vegetation, materials, animals, visibility, personal comfort, and well-being.

3. Maximum Desirable Level (M.D.L.)
   This level defines the long term goal for air quality and provides a basis for an anti-degradation policy for the pristine areas of Manitoba and for the continuing development of control technology. At this level, there would be no adverse biological effect on any receptor.

Neither objectives nor guidelines have been established, as yet, for inhalable particulate, PAH, and VOC.

TABLE 1

MANITOBA AIR QUALITY OBJECTIVES AND GUIDELINES FOR TOTAL SUSPENDED PARTICULATE

Contaminant	Time Period Measured	Max. Toierable Level (ug/m^3)	Max. Acceptable Level (ug/m^3)	Max. Desirable Level (ug/m^3)
Total Suspended Particulate	24 Hour Average	400	120	*
	Annual Geometric Mean	*	70	60

* No objective or guideline set

PROCEDURES

A) VOLATILE ORGANIC COMPOUNDS (VOC)

Sampling was performed using equipment and analytical facilities provided by the Pollution Measurement Division of Environment Canada, in Ottawa.

Ambient air samples were collected in 6 litre, stainless steel polished canisters. A stainless steel metal bellows pump with capillary flow restrictor to control sampling flow rate was used to collect the air sample. Before sampling, each canister was cleaned by alternately evacuating the canister to a 5 torr vacuum, and pressurizing to 30 psi with uitra high purity (UHP) air. This cycle was repeated 3 times, with the last fill of zero air being analyzed to verify that the canister was clean. The prepared canisters were then sent into the field and evacuated to 5 torr.

Sampling flow rates were chosen to allow the canister to be filled to a pressure of 15 to 25 psi over a period of 12 to 24 hours. Total sample volumes ranged from 8 to 12 litres. After sampling, canisters were capped and returned to the Environment Canada River Roads Environmental Technology Centre, in Ottawa, for analysis.

Samples were pre-concentrated before analysis, using a cryogenic trap. Analysis was performed using a gas chromatograph equipped with a fused silica capillary column and a Hewlett-Packard 5970 Series Mass Selective Detector (MSD).

More detailed descriptions of sampling and analytical methodology for VOC have been published by Environment Canada (10) and other agencies (11,12,13,14,15).

B) POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)

Sampling for PAH was undertaken using a modified high volume air sampler method, developed by Environment Canada (16). Compounds were adsorbed on plugs of polyurethane foam [PUF], which had been soxhlet extracted for 24 hours using methanol and cyclohexane. The cleaned PUF plugs were loaded into glass tubes, which in turn were loaded into

aluminum canisters, with teflon gaskets, spacers and end caps. Aluminum cap rings were used to seal the canister assembly, which was then ready for shipping to the field site. A preweighed, teflon coated glass fibre prefilter was used in the sampling train, to trap particulate.

Ambient air is drawn through the filter/canister assembly, using the modified high volume air sampler. The sampler operated at a flow rate of 600 to 700 liters per minute. Total air sample volumes for the study ranged between 870 and 980 cubic meters. After sampling, cartridges and filters were sent to the W. M. Ward Technical Services Laboratory in Winnipeg for analysis.

The exposed filters and PUF plugs were Soxhlet extracted, and analyzed using a gas chromatography / mass spectroscopy system. Analyses were performed for 18 compounds (see Appendix A for compound properties and structures).

C) TOTAL SUSPENDED PARTICULATE (TSP)

Sampling for TSP was conducted using a standard high volume particulate sampler equipped with teflon filters. This sampling methodology was consistent with the standard reference method developed by Environment Canada (17).

Teflon filters, pre-weighed at the W. M. Ward Technical Services Laboratory, were used as sampling media to trap particulate suspended in air. Samples were analyzed using standard gravimetric techniques for particulate.

D) INHALABLE PARTICULATE

A modified high volume air sampler equipped with an Anderson Model 7000 size selective particulate sampling head was used for measurement of inhalable particulate. This system uses the principle of cascade impaction to separate respirable particulate with a cut off size of 10 micrometers.

Samples were collected on preweighed glass fibre filters using standard high volume air sampling procedures. Samples were submitted to the W. M. Ward Technical Services Laboratory for gravimetric particulate analysis. Results were reported as concentrations of mass per unit volume of air.

MONITORING SITES

Samples were collected at a site, designated station 2032, at 3233 Silver Ave., Winnipeg. This station was situated in a residential area approximately 11.5 kilometers west of the city centre (see Appendix B, Site Map). The intakes for the samplers were placed 10 metres above ground level. The nearest major traffic route was approximately 800 metres east of the site. The nearest industrial area was approximately 3 kilometres east of the site.

Siting was determined on the basis of meteorological data taken during known incidents of smoke attributed to agricultural burning in the vicinity of Winnipeg. Prevailing wind direction during these incidents was found to vary between 180 and 300 degrees, corresponding with areas of high flax production. As it was difficult to predict when burning would occur, the location was chosen with the intent of providing the highest probability of impingement during an incident, within the siting criteria.

RESULTS

Ten samples were collected for both VOC and PAH. The samples were analyzed for 91 VOC and 18 PAH compounds, and the results are listed in Tables 2 and 3, respectively. VOC data are reported in units of micrograms per cubic metre (ug/m^3), while PAH is shown in units of nanograms per cubic metre (ng/m^3), both corrected to 25 degrees C and 1 atmosphere of pressure. (Note: 1000 ng = 1 ug).

Ten samples were collected for both total and inhalable particulate during the course of the study. Results are listed in Table 4, and are reported in units of micrograms per cubic metre of air (ug/m^3), corrected to 25 degrees C and 1 atmosphere of pressure.

A summary of meteorological conditions, which were observed on-site during the monitoring period, is given in Table 5.

TABLE 2
VOC CONCENTRATIONS (ug/m^3)
SITE 2032 - WINNIPEG

COMPOUNDS	1989 Aug. 22	Aug. 25	Aug. 30	Sept. 01	Sept. 07	Sept. 12
PROPYLENE	0.80	0.46	0.32	0.50	nd	0.82
PROPANE	28.16	nd	19.01	nd	nd	nd
FREON 22	nd	0.50	nd	0.47	0.49	0.69
FREON 12	6.23	8.03	1.18	7.51	0.63	0.64
2-METHYL PROPANE	8.08	2.25	5.58	1.14	2.44	1.12
FREON 114	0.40	0.32	0.25	0.27	0.28	0.41
VINYL CHLORIDE	nd	nd	nd	nd	nd	nd
1-BUTENE	4.47	2.19	1.79	1.14	3.75	2.15
1,3-BUTADIENE	0.67	nd	0.49	nd	0.23	nd
BUTANE	26.72	2.68	11.73	3.28	5.58	3.07
trans-2-BUTENE	1.00	0.21	0.36	0.18	0.21	nd
2,2-DIMETHYL PROPANE	0.22	0.21	0.21	nd	0.18	nd
1-BUTYNE	nd	nd	nd	nd	nd	nd
cis-2-BUTENE	0.57	nd	0.24	nd	nd	nd
2-METHYL BUTANE	22.18	3.12	13.27	3.46	6.24	4.65
FREON 11	2.59	2.08	2.00	1.57	2.17	1.59
1-PENTENE	0.77	nd	0.33	nd	nd	nd
PENTANE	13.16	2.35	7.94	2.47	3.68	2.28
1,1-DICHLOROETHENE	0.24	0.15	nd	nd	nd	nd
DICHLOROMETHANE	2.47	1.06	1.12	0.70	0.95	0.77
2,2-DIMETHYLBUTANE	0.73	nd	0.44	nd	0.20	nd
trans-1,2-DICHLOROETHYLENE	nd	nd	nd	nd	nd	nd
1,1-DICHLOROETHYLENE	nd	nd	nd	nd	nd	nd
CYCLOPENTANE	1.15	0.14	0.70	0.24	0.41	0.20
2,3-DIMETHYLBUTANE	1.71	0.18	0.66	0.24	0.36	0.26
2-METHYLPENTANE	11.42	4.37	7.31	3.39	7.18	5.80
3-METHYLPENTANE	5.58	0.86	2.63	1.09	1.82	1.34
1-HEXANE	nd	nd	nd	nd	nd	nd
BROMOCHLOROMETHANE	nd	nd	nd	nd	nd	nd
HEXANE	6.39	0.77	2.25	1.13	1.23	0.92
CHLOROFORM	0.95	0.47	0.35	0.27	0.35	0.23
1,2-DICHLOROETHANE	0.13	nd	0.18	0.12	0.16	0.13
METHYLCYCLOPENTANE	2.72	0.31	1.02	0.41	0.59	0.43
2,4-DIMETHYLPENTANE	nd	nd	nd	nd	0.58	0.55
1,1,1-TRICHLOROETHANE	3.44	1.62	1.52	1.90	1.59	1.54
BENZENE	5.27	1.14	3.37	1.16	1.71	1.12
CARBON TETRACHLORIDE	1.04	1.03	0.85	1.22	0.90	1.01
CYCLOHEXANE	0.88	0.21	0.22	0.42	0.20	nd
2-METHYLHEXANE	2.92	0.99	0.99	0.64	0.37	0.89
2,3-DIMETHYLPENTANE	4.91	0.29	1.07	0.54	0.61	0.57
3-METHYLHEXANE	3.25	0.99	1.19	0.71	1.43	1.28
DIBROMOMETHANE	nd	nd	nd	nd	0.40	0.39
1,2-DICHLOROPROPANE	nd	nd	0.28	nd	nd	0.40
BROMODICHLOROMETHANE	0.19	0.17	0.20	0.27	0.41	0.37
TRICHLOROETHYLENE	0.25	nd	nd	0.15	nd	0.15
2,2,4-TRIMETHYLPENTANE	6.58	0.55	1.42	0.69	nd	0.76
HEPTANE	2.29	0.26	0.60	0.53	0.66	0.50
cis-1,3-DICHLOROPROPANE	nd	nd	nd	nd	nd	nd
METHYLCYCLOHEXANE	1.17	nd	0.55	0.24	0.35	0.35
2,5-DIMETHYLHEXANE	0.34	nd	nd	nd	nd	nd
trans-1,3-DICHLOROPROPANE	nd	nd	nd	nd	nd	nd
1,1,2-TRICHLOROETHANE	0.18	nd	nd	nd	nd	nd
2,3,4-TRIMETHYLPENTANE	1.48	0.15	0.31	nd	0.24	0.23
TOLUENE	13.50	2.36	5.01	2.22	3.77	2.54
3-METHYLHEPTANE	0.66	0.92	0.18	nd	0.18	0.17
DIBROMOCHLOROMETHANE	nd	nd	nd	0.23	nd	nd
2,2,5-TRIMETHYLHEXANE	0.36	nd	0.08	nd	nd	nd
ETHYLENE DIBROMIDE	nd	nd	0.23	0.27	nd	nd
OCTANE	0.47	0.09	0.14	0.10	0.10	0.12

TABLE 2 [continued]
VOC CONCENTRATIONS (ug/m^3)
SITE 2032 - WINNIPEG

COMPOUNDS	1989 Aug. 22	Aug. 25	Aug. 30	Sept. 01	Sept. 07	Sept. 12
TETRACHLOROETHYLENE	1.21	0.29	0.86	0.37	0.39	0.29
CHLOROBENZENE	0.35	0.30	0.25	0.27	0.21	0.14
ETHYLBENZENE	6.85	0.79	0.89	0.63	0.85	0.58
m-,p-XYLENE	30.13	2.96	3.66	1.93	2.87	2.07
BROMOFORM	nd	0.39	nd	0.51	nd	nd
STYRENE	0.75	0.24	0.36	0.34	0.45	0.22
1,1,2,2-TETRACLOROETHANE	0.94	0.72	0.71	nd	1.28	nd
o-XYLENE	11.29	0.97	1.37	0.79	1.12	0.87
n-NONANE	2.26	0.40	0.43	0.48	0.49	0.36
ISOPROPYLBENZENE	0.53	0.14	0.13	0.19	0.14	0.17
n-PROPYLBENZENE	1.43	0.14	0.22	0.24	0.19	0.21
3-ETHYLBENZENE	5.23	0.38	0.72	0.64	0.52	0.63
4-ETHYLBENZENE	2.42	0.20	0.40	0.33	0.27	0.33
1,3,5-TRIMETHYLBENZENE	3.00	0.22	0.38	0.36	0.29	0.34
2-ETHYLBENZENE	2.40	0.17	0.26	0.30	0.19	0.24
1,2,4-TRIMETHYLBENZENE	12.55	0.98	1.66	1.34	1.28	1.30
DECANE	6.37	0.43	0.32	0.73	0.56	0.45
1,3-DICHLOROBENZENE	nd	0.16	nd	0.65	nd	0.15
iso-BUTYLBENZENE	0.19	0.10	nd	0.24	nd	0.08
1,4-DICLOROBENZENE	1.39	0.62	0.35	0.52	0.52	0.97
sec-BUTYLBENZENE	0.30	nd	nd	nd	nd	nd
p-CYMENE	0.36	0.65	0.28	0.96	0.31	0.57
1,2-DICHLOROBENZENE	0.11	0.19	nd	0.89	nd	0.20
1,3-DIETHYLBENZENE	0.53	0.26	0.23	1.02	0.27	0.16
1,4-DIETHYLBENZENE	2.99	0.25	0.17	0.48	0.22	0.29
n-BUTYLBENZENE	0.92	0.18	0.10	0.42	0.08	0.17
1,2-DIETHYLBENZENE	0.19	0.16	0.10	0.43	0.10	0.10
1,2,4-TRICHLOROBENZENE	0.25	0.53	0.14	2.91	nd	0.42
DODECANE	1.69	0.76	0.32	1.61	0.49	0.62
NAPHTHALENE	2.16	0.95	0.49	0.88	0.69	1.07
HEXACHLOROBUTANE	0.59	1.32	nd	4.76	nd	0.41
HEXYLBENZENE	0.52	0.68	0.19	1.92	nd	0.16

nd - not detected

TABLE 3
PAH CONCENTRATIONS (ng/m^3)
STATION 2032 - WINNIPEG

COMPOUNDS	1989 Aug. 22	Aug. 25	Aug. 30	Sept. 01	Sept. 03
ACENAPHTHYLENE	1.64	0.13	0.52	0.11	nd
ACENAPHTHENE	0.21	nd	0.11	nd	nd
FLUORENE	1.48	0.35	1.91	0.45	0.47
PHENANTHRENE	10.12	0.95	3.20	3.08	4.13
ANTHRACENE	nd	0.22	1.15	0.29	0.16
FLUORANTHENE	4.64	0.65	2.38	0.62	0.75
PYRENE	3.64	0.60	2.33	0.63	0.65
BENZO(a)FLUORENE	0.45	0.17	0.64	nd	0.15
BENZO(b)FLUORENE	0.43	nd	0.38	nd	0.14
BENZO(a)ANTHRACENE	0.51	0.80	0.13	0.12	nd
CHRYSENE	0.17	nd	1.29	0.18	0.14
BENZO(b)FLUORANTHENE	0.43	0.13	1.14	0.17	0.12
BENZO(k)FLUORANTHENE	nd	nd	1.00	nd	nd
BENZO(e)PYRENE	0.20	nd	0.83	nd	nd
BENZO(a)PYRENE	0.17	nd	0.71	nd	nd
INDENO (1,2,3-cd) PYRENE	0.25	nd	0.96	0.11	0.15
DIBENZO-(a,c)&(a,h)ANTHRACENE	nd	nd	0.19	nd	nd
BENZO(g,h,i)PERYLENE	0.34	nd	1.24	0.11	nd
TOTAL PAH (ng/m^3)	24.68	4.00	20.11	5.87	7.00
TSP (ug/m^3)	62.2	34.0	43.8	20.2	25.2

COMPOUNDS	1989 Sept. 05	Sept. 07	Sept. 12	Sept. 13	Sept. 15
ACENAPHTHYLENE	nd	nd	nd	0.32	0.12
ACENAPHTHENE	nd	nd	nd	0.24	nd
FLUORENE	0.91	1.02	1.01	0.78	1.06
PHENANTHRENE	6.81	7.90	5.11	2.59	8.66
ANTHRACENE	0.26	1.04	0.32	0.21	0.81
FLUORANTHENE	1.23	2.08	1.03	0.57	1.59
PYRENE	1.23	1.87	1.03	0.62	1.82
BENZO(a)FLUORENE	0.20	0.69	0.21	nd	0.37
BENZO(b)FLUORENE	0.16	0.32	0.16	0.15	0.17
BENZO(a)ANTHRACENE	nd	0.23	0.12	nd	nd
CHRYSENE	0.13	0.43	0.17	nd	0.23
BENZO(b)FLUORANTHENE	0.15	0.37	nd	0.16	nd
BENZO(k)FLUORANTHENE	nd	nd	nd	nd	nd
BENZO(e)PYRENE	nd	0.15	0.12	nd	nd
BENZO(a)PYRENE	nd	nd	nd	nd	nd
INDENO (1,2,3-cd) PYRENE	0.09	0.14	0.12	0.10	nd
DIBENZO-(a,c)&(a,h)ANTHRACENE	nd	nd	nd	nd	nd
BENZO(g,h,i)PERYLENE	0.13	0.17	0.23	0.25	0.12
TOTAL PAH (ng/m^3)	11.80	16.41	9.63	5.99	14.95
TSP (ug/m^3)	36.9	39.6			30.2

nd - NOT DETECTED

TABLE 4
PARTICULATE CONCENTRATION
STATION 2032 - WINNIPEG

DATE	TOTAL SUSPENDED PARTICULATE(TSP) [ug/m^3]	INHALABLE PARTICULATE (IP) [ug/m^3]	IP / TSP RATIO
AUG. 22 /89	39.1	27.5	0.70
AUG. 25 /89	34.0	23.7	0.70
AUG. 30 /89	43.8	38.8	0.88
SEPT. 1 /89	20.2	13.5	0.66
SEPT. 3 /89	25.2	17.5	0.69
SEPT. 5 /89	36.9	29.0	0.78
SEPT. 7 /89	39.6	34.0	0.86
SEPT.12 /89		13.9	
SEPT.13 /89	11.6	7.9	0.68
SEPT.15 /89	30.2	18.4	0.61

TABLE 5
METEOROLOGICAL DATA
STATION 2032 - WINNIPEG

DATE	WIND SPEED (km/hr)	WIND DIRECTION (DEGREES)	TEMPERATURE (DEGREES C)	COMMENTS
AUGUST 22	8	112	19	Smoke Odour Evening Haze
AUGUST 25	27	180	22	Clear
AUGUST 30	5	157	12	Smoke and Ground Fog 03:30 - 10:00 [Vis. <20 m]
SEPTEMBER 1	14	337	14	Clear
SEPTEMBER 3	22	180	19	Clear Rain Overnight
SEPTEMBER 5	12	225	11	Smoke Haze during Day
SEPTEMBER 7	19	225	18	Smoke Odour
SEPTEMBER 12	12	270	8	Smoke Haze / Morning Odour
SEPTEMBER 13	12	202	14	Clear
SEPTEMBER 15	18	202	20	Smoke Odour in Morning

DISCUSSION

Smoke incidents from agricultural burning normally occur in the evening hours during late summer and early fall, after harvest has been completed. Severe smoke episodes may be characterized by the presence of a strong smoky odour in the affected area, coupled with obscured visibility. In some cases, only the strong odour may be noted.

This phenomenon is observed as a result of two factors related to meteorological conditions. First, most burning is initiated during periods of calm wind conditions, to allow fires to be controlled. Little turbulence is generated, and smoke constituents are not allowed to dilute or dissipate. Surface inversion conditions are prevalent during this time of the year, and are facilitated by the presence of warm air masses from the agricultural burning. Combustion products produced from the fires are held close to the ground by the inversion, and travel in the prevailing wind direction. Both conditions contribute directly to observed smoke incidents.

Little literature has been published regarding the potential health hazards associated with smoke from agricultural burning. It is known that people suffering from respiratory disorders such as asthma have complained of severe discomfort during these episodes. A number of highway traffic accidents, mostly in rural areas, have also occurred during smoke events. Some have involved fatalities.

Surveys have been performed in a number of jurisdictions to examine emissions from various types of combustion processes (18, 19, 20). A preliminary study undertaken in 1987 indicated that elevated levels of particulate, PAH, and VOC could be present during smoke incidents affecting the city of Winnipeg. No study was initiated during the 1988 harvest period, as little burning was carried out near Winnipeg, due to extreme drought conditions.

Most burning in the vicinity of Winnipeg was found to originate in areas to the northwest and southwest of the city. Cultivation of cereal grains and flax predominate in these areas. Survey data compiled by the Manitoba Department of Agriculture in September, 1989 (21) indicated that 10-23% of cereal crop stubble and residue in the municipalities surrounding Winnipeg was being burned, a drop from the 14-34% recorded for the same areas in 1987. Burning of flax continues in areas where this crop is grown, with 13-89% of fields burned.

This practice is prevalent with flax straw, if it cannot be sold for use in the fibre processing industries, as the fibre is extremely tough, and does not decompose readily.

Despite early spring rains, most of the summer in the province was hot and dry, with drought conditions prevailing in June and July. As a result, crop yields were light, and of poor quality. Harvesting commenced in the first week of August, with agricultural burning starting around the third week in August. A number of incidents were observed in August and September, mostly in the late evening or early hours of the morning. These were characterized by the presence of a smoky odour in the vicinity, with a haze obscuring visibility. In one case (August 30, 03:30-10:00) a combination of smoke and ground fog created conditions where visibility was less than 50 feet. Winds were light, varying between northwesterly and southerly directions.

Sampling for all parameters commenced at site 2032 on August 22, 1989. Ten samples were taken for TSP, Inhalable Particulate, and PAH between August 22 and September 15. Six samples were taken for VOC. Background samples were taken for all parameters on August 25, September 1 and 13, 1989, when no burning was observed or reported.

None of the total suspended particulate levels were found to exceed the 24 hour Average Maximum Acceptable Limit of 120 ug/m^3. TSP levels during observed smoke incidents ranged between 30 and 43 ug/m^3. Mean background levels were 22 ug/m^3. Mean TSP levels observed at a Winnipeg NAPS station with a similar profile (299 Scotia St.), average at approximately 30 ug/m^3, based upon historical data for 1983-85 (22, 23, 24, 25).

Samples for Inhalable Particulate were found to range between 13 and 39 ug/m^3 during smoke events. No standards have been promulgated in Canada for this parameter. Samples for this parameter taken at the downtown NAPS station in Winnipeg (65 Ellen St.) from May 1984 - December 1987 (26) have averaged at 31 ug/m^3, with a maximum value of 112 ug/m^3. However, new standards published by the Environmental Protection Agency in the United States (27) have set a 24 hour average primary standard for respirable particulate (10 micron cutoff size) of 150 ug/m^3.

The ratio of inhalable particulate to total particulate has been used as a means of determining the relationships between these two methods of sampling, to allow historical

data to be interpreted, and as a quality control check for particulate loading. The mean ratio of IP / TSP loadings during the study was 0.73. This average is higher than that determined during the previous study, and was also higher than the ratio reported for the 65 Ellen St. NAPS site in Winnipeg (28, 29). This is indicative of a higher fraction of fine particulate being present in the samples collected during this study.

PAH monitoring indicated that low levels of the 18 compounds examined during this study were present on all ten days when sampling was initiated. Concentration levels were well below those observed in the 1987 PAH surveys. Total PAH concentrations during background days ranged between 4 and 7 ng/m^3, while PAH levels varied between 14 and 25 ng/m^3 during incidents. The highest concentrations were recorded on August 22, 1989, with elevated levels of phenanthrene, acenaphthylene, fluorene, fluoranthene, and pyrene, in comparison with background. Elevated levels of phenanthrene, fluorene, fluoranthene and pyrene were recorded on five other days. This profile of PAH is similar to that observed during the 1987 study. No air standards have been set for the PAH examined in this study. However, comparison with studies performed in other jurisdictions (30,31), indicate that these levels are low in comparison to those produced by other emission sources.

Monitoring for VOC indicated that 83 of the 91 compounds were detected during the study. A number of these chemicals were found at very low concentrations, and may be considered near background. Other compounds exhibited little variability in concentration throughout the study. These compounds were mostly chlorofluorocarbons and chlorinated hydrocarbons, and were not considered as products emitted from combustion processes.

Certain VOC monitored were found to vary in concentration throughout the study. Elevated levels of a number of aromatic compounds were noted during smoke episodes, with the highest concentrations being observed on August 22, 1989. Toluene (13.5 ug/m^3), m, p-xylene (30.13 ug/m^3), o-xylene (11.29 ug/m^3), and 1,2,4-trimethylbenzene (12.55 ug/m^3), were all found at levels significantly above background concentrations. While results were lower than those observed in 1987, the compound profile was found to be similar.

None of the incidents monitored during this study approached the severity of those in 1987. Only one day was observed in the vicinity of Winnipeg with highly obscured visibility (early morning, August 30). From direct observation of this incident, it was determined that the

situation was related more to ground fog in the area, although a smoky odour could be detected. For all the parameters examined, monitoring results were generally lower than those observed in 1987. This could be attributed to a combination of factors, as follows:

1) Crop yields were generally smaller than those of 1987, due to hot and dry conditions in the summer of 1989. With less material to burn, less smoke would be produced.

2) Data distributed by the Manitoba Department of Agriculture, indicated that less burning of cereal crop stubble occurred during the 1989 season, in the areas surrounding Winnipeg. As these crops represent 70 to 80% of cultivation, a decrease in burning would significantly affect the number of observed smoke incidents.

3) Meteorological conditions may have been conducive to increased air turbulence during the day, effectively diluting the smoke before inversion conditions could form.

CONCLUSIONS

Due to the sporadic nature and finite number of smoke-in-air events that occur, only limited opportunity is available for sampling each year. While none of the incidents monitored in August and September of 1989 approached the severity of those observed in 1987, some conclusions may be made, as follows:

1) Elevated levels of both total and inhalable particulate were observed at the sampling site during known smoke events in the Winnipeg area. None of the TSP levels were found to exceed the 24 hour Average Maximum Acceptable Level of 120 ug/m^3. A larger fraction of fine particulate in the respirable range (<10 um) was noted in the samples taken.

2) Elevated levels of acenaphthylene, fluorene, fluoranthene, pyrene and phenanthrene were observed during survey monitoring for PAH, in comparison to background. These levels were observed during known incidents of agricultural burning in the vicinity of Winnipeg. Compound profiles were similar to those observed during the 1987 study, although ambient concentrations were lower than those observed in the previous study.

3) Elevated levels of a number of aromatic compounds were noted during the study, including Toluene, m,p-Xylene, o-Xylene, and 1,2,4-Trimethylbenzene, during smoke incidents in the vicinity of Winnipeg. These compound profiles were similar to those observed in the 1987 study, although ambient levels were lower than those observed previously.

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Appendix A:

PROPERTIES AND STRUCTURES

OF

POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)

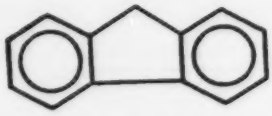
TABLE A1 - Properties of PAH commonly measured in Ambient Air

COMPOUND	MOLECULAR FORMULA	MOLECULAR WEIGHT
ACENAPHTHYLENE	C12H8	152.2
ACENAPHTHENE	C12H10	154.2
FLUORENE	C13H10	166.2
PHENANTHRENE	C14H10	178.2
ANTHRACENE	C14H10	178.2
FLUORANTHENE	C16H10	202.3
PYRENE	C16H10	202.3
BENZO(a)FLUORENE	C17H12	216.3
BENZO(b)FLUORENE	C17H12	216.3
BENZO(a)ANTHRACENE	C18H12	228.3
CHRYSENE	C18H12	228.3
BENZO(b)FLUORANTHENE	C20H12	242.3
BENZO(k)FLUORANTHENE	C20H12	242.3
BENZO(e)PYRENE	C20H12	252.3
BENZO(a)PYRENE	C20H12	252.3
DIBENZO(a,c)&(a,h)ANTHRACENE	C22H14	278.4
BENZO(g,h,i)PERYLENE	C22H12	276.3

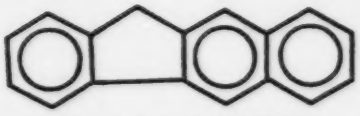
Figure A1: Structures of selected Polynuclear Aromatic Hydrocarbons

ACENAPHTHYLENE

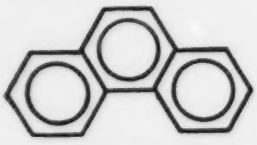
ACENAPHTHENE



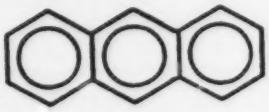
FLUORENE



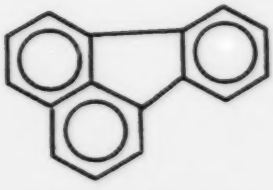
BENZO(b) FLUORENE



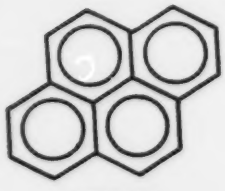
PHENANTHRENE



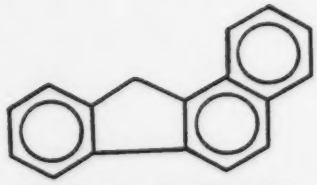
ANTHRACENE



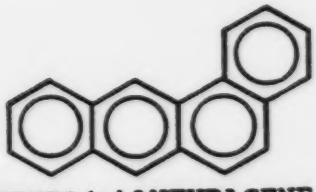
FLUORANTHENE



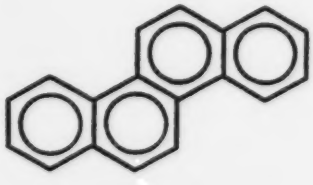
PYRENE



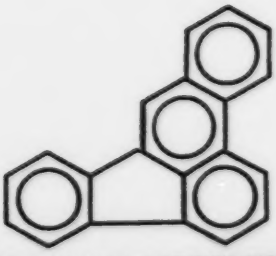
BENZO(a) FLUORENE



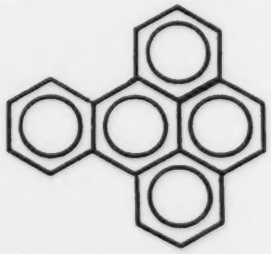
BENZO(a) ANTHRACENE



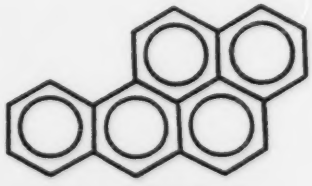
CHRYSENE



BENZO(b) FLUORANTHENE

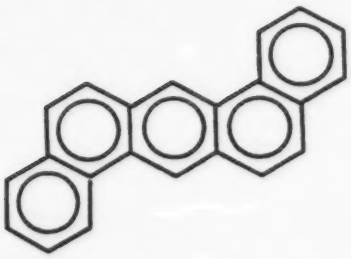


BENZO(e) PYRENE



BENZO(a) PYRENE

Figure A1: Structures of selected Polynuclear Aromatic Hydrocarbons (cont'd)



DIBENZO-(a,h) ANTHRACENE

BENZO(g,h,i)PERYLENE

Appendix B:

SITE MAP

SITE MAP

WINNIPEG

MONITORING STATION 2032